Commercial Production of GREENHOUSE TOMATOES

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CONTENTS

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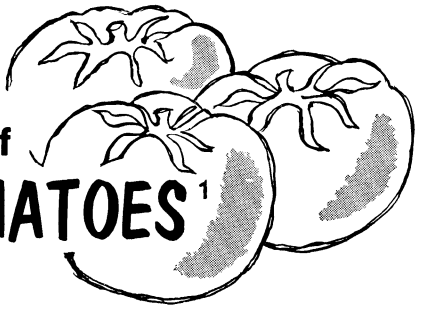
Commercial Production of GREENHOUSE TOMATOES[1]



By William S. Porte, *pathologist, Horticultural Crops Research Branch,* and Floyd F. Smith, *principal entomologist, Entomology Research Branch, Agricultural Research Service*

Growing of tomatoes in greenhouses is one of the most technical and intensive of agricultural enterprises. It can also become one of the most profitable if the available technical information and the many facets of the art of growing greenhouse tomatoes are thoroughly understood.

The beginner should learn all he can about the effects of sunlight, heat, water, air, and soil on greenhouse tomatoes before assuming the responsibility for growing a crop. In addition to obtaining the advice of experienced agriculturists and studying the literature written on greenhouse culture, the beginner will gain valuable knowledge by working for a successful grower. After he has gained some experience in growing hothouse tomatoes it is safer to build, buy, or rent a small greenhouse and accumulate the additional know-how essential for successful gradual expansion of the enterprise as profits seem to warrant.

In 1950 nearly every State had some commercial greenhouses used for the production of vegetables. The most extensive development has been in the great industrial area north of the Ohio and east of the Mississippi Rivers. The largest commercial vegetable greenhouses are located in the environs of the following cities: Cleveland, Boston, Indianapolis, Cincinnati, Toledo, Terre Haute, Grand Rapids, and Milwaukee. In 1950 Ohio led the States with 650 acres under glass; followed by Indiana, 150 acres; Massachusetts, 100 acres; and Michigan, Illinois, New York, and Wisconsin, approximately 50 acres each. The rest of the States have around 1,000 additional acres of vegetables under glass.

The three leading vegetable greenhouse crops grown in the United States are tomatoes, lettuce, and cucumbers. The wholesale market value of these hothouse vegetables in 1949 is shown in table 1 for the 11 leading States and the totals for the whole country. The tomato is by far the most important glasshouse vegetable crop, with a gross annual wholesale value of more than $10 million.

LOCATING A COMMERCIAL GREENHOUSE

A greenhouse close to a good local market has a big advantage over a location far distant from markets. It not only saves much transportation expense but reduces time in transit, enabling the grower to market the highest quality vine-ripened

[1] Supersedes Farmers' Bulletin 1431, Greenhouse Tomatoes.

TABLE 1.—*Annual wholesale market value of vegetables grown under glass in the United States in 1949* [1]

States	Tomatoes	Lettuce	Cucumbers	All other vegetables
Ohio	$6, 803, 550	$659, 039	$364, 931	$114, 594
Indiana	914, 542	246, 454	160, 550	16, 241
Massachusetts	533, 161	44, 486	111, 536	70, 553
Illinois	269, 660	37, 520	107, 153	4, 928
Michigan	266, 295	109, 891	11, 152	31, 679
Pennsylvania	217, 320	13. 795	60. 602	2, 643
Wisconsin	196, 253	25, 102	4, 466	18, 032
New York	187, 422	15, 899	6, 500	20, 175
Missouri	124, 153	144, 576	17, 075	500
Washington	93, 219	8, 412	87, 339	640
Oregon	93, 150		75, 077	
All others	398, 673	88, 247	270, 795	18, 880
Total for United States	10, 077, 398	1, 393, 021	1, 277, 176	298, 865

[1] Data compiled by Agricultural Marketing Service from U. S. Census of Agriculture, 1950.

tomatoes. Fuel, water, and labor at reasonable cost are essential, and a fertile, medium-textured soil is an advantage.

Clear air free from smoke and gases poisonous to plants and a relatively high percentage of sunshine during the short days of fall and winter are desirable. A site fully exposed to sunlight but protected from winds and storms by windbreaks will save fuel and breakage of glass. However, many thriving greenhouse enterprises are located in areas subject to much cloudy weather.

The position of a greenhouse with reference to the points of the compass has little effect on growing tomatoes in this country. A north-south direction provides a more uniform distribution of light throughout the year and enables the construction of headhouses at the north end of the range. In greenhouses constructed in an east-west direction, crop rows running north and south provide better exposure to sunlight during short winter days.

The greenhouse site should have good air and water drainage. Stale moisture-laden air favors tomato foliage diseases, especially leaf mold. Excess water from low situations is often drained into concrete cisterns or ponds. Water collected from soil drainage should not be used to irrigate crops. This water may gradually increase the concentrations of soluble salts in the soil and also tend to spread various diseases and pests. However, rainwater collected from roofs into a separate cistern is safe to use for irrigating crops.

TYPES OF GREENHOUSES

There are many types of greenhouses—from the small shed roof "lean-to" houses constructed of wood-frame sash to the large modern steel-frame houses with truss-supported roofs. Most new houses are of steel, wood, and masonry construction with even-spanned roofs (fig. 1). These modern houses with 6 feet or more of headroom at the eaves are the most satisfactory type for growing tomatoes. Standard plans and specifications for greenhouses are available from manufac-

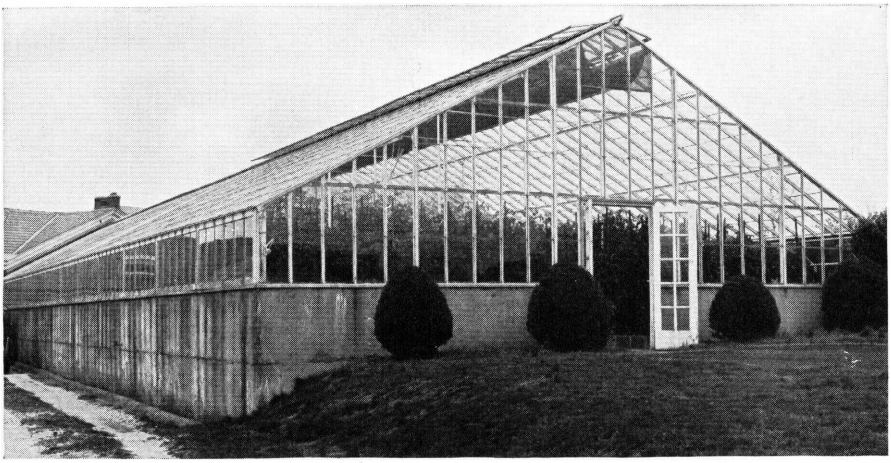


FIGURE 1.—*A medium-sized greenhouse unit of steel, wood, and masonry construction.*

turers of this equipment, and the details of construction and heating are fully discussed in Farmers' Bulletin 1318, Greenhouse Construction and Heating.[2]

INTERNAL FEATURES OF GREENHOUSE

Systems of Watering

Water-supply pipes are usually placed underground, and short vertical pipes fitted with garden-hose faucets are attached at intervals so that any part of the house can be watered with 50 to 75 feet of garden hose. In most commercial establishments, however, watering is done with hose only when the plants are first set out and their water requirements are relatively small. Many of the larger houses are equipped with a permanent system of pipes and nozzles for sprinkler irrigation either overhead or near the soil surface.

Automatic watering machines or hose reels are now in limited use. These facilities cut labor costs. A skid with spray nozzles and hose attached is pulled to the end of the row and the machine winds the hose back up.

Less frequently, subirrigation systems composed of lines of unglazed agricultural tile are used. These are spaced 2 to 4 feet apart and laid end to end below plow depth and enable the greenhouse operator to water the plants without wetting the surface of the soil; 3- or 4-inch tile in 1-foot lengths laid with about one-quarter inch between pieces is generally used.

Each tile line is provided with an opening at both ends so water can be conducted into it from either end through garden hose until the soil is sufficiently irrigated. In tile lines more than 150 feet long, extra openings should be provided about every 100 feet so the soil will be more evenly moistened throughout the length of the bed. Operators often use several lines of hose to water simultaneously, thereby saving much time. Sometimes permanent installations of water pipes connected with the tile lines are used to speed up subirrigation.

The tile may also be used to facilitate steaming the soil. This

[2] This and other Farmers' Bulletins listed are available free from the Office of Information, U. S. Department of Agriculture, Washington 25, D. C.

may be accomplished by inserting a steampipe manifold into the open ends of the tile lines. All openings are then closed with burlap or rag plugs smeared over with clay mud. The subirrigation tile lines also provide extra soil aeration and drainage. Where permanent overhead or surface irrigation systems are used, tile are usually installed exclusively for steaming the soil.

Ground Beds

When tomatoes were first grown in greenhouses practically all the plants were grown on raised benches, because it was thought that bottom heat under the benches was essential in order to obtain a good crop. Later it was learned that better crops could be grown at floor level in ground beds without any bottom heat.

Ground beds are better than raised benches for tomatoes because the soil can be more easily and economically prepared. Power machinery is often used in the larger houses. Tomato plants are tall growing, needing 6 feet or more for growth. Tomatoes growing in ground beds are easier to water, to train, and to harvest. The high cost of constructing and maintaining benches is now largely eliminated from greenhouse tomato culture.

Essential Walks

Most permanent walks can be eliminated from tomato greenhouses. Concrete or brick walks interfere with the use of power machinery, make soil sanitation measures less effective, and tend to reduce the number of tomatoes that can be grown in each greenhouse unit. Essential temporary walks can be provided by board runways between certain rows of plants. These are picked up and stored as soon as the crop is harvested. Permanent concrete walks that are necessary should be laid, wherever possible, next to heating lines where it is too hot for good plant growth.

CROPPING PLANS COMMONLY USED

Many greenhouses are used for the production of two or more different crops. Tomatoes, lettuce, and cucumbers are the three most important vegetable crops grown in greenhouses. These crops are used in various sequences and in combination with other vegetable and flower crops. While no definite cropping plans suited to the needs of all growers located in different parts of the United States can be given, the crop sequences here suggested are used by many greenhouse growers in some important vegetable-forcing communities.

Plan 1

Tomatoes.—Seed sown July 1 to 15; plants set in houses August 15 to 30; vines removed December 15 to 31.

Lettuce.—Seed sown November 15 to 30; plants set in houses December 15 to 31; crop harvested March 15 to 31.

Cucumbers.—Seed sown February 1 to 15; plants set in houses April 1 to 15; vines removed July 1 to 15.

Plan 2

Tomatoes.—Seed sown October 25 to November 10; plants set in houses about January 10; vines removed July 1 to August 1.

Tomatoes.—Seed sown June 15 to July 1; plants set in houses August 1 to 15; vines removed December 15 to January 1.

Plan 3

Tomatoes.—Seed sown December 15 to January 1; plants set in houses February 1 to 15; vines removed July 1 to 15.

Chrysanthemums.—Plants set in houses July 1 to 15; plants removed December 15 to January 1.

Plan 4

Tomatoes.—Seed sown December 15 to January 1; plants set in houses February 1 to 15; vines removed July 1 to 15.

Tomatoes.—Seed sown June 15 to July 1; plants set in houses August 1 to 15; vines removed December 1 to 15.
Radishes.—Seed sown December 1 to 15; plants removed February 1 to 15.

Plan 5

Lettuce.—Seed sown August 1 to 15; plants set in houses September 1 to 15; crop harvested November 15 to 30.
Lettuce.—Seed sown October 15 to 30; plants set in houses November 15 to 30; crop harvested February 1 to 28.
Tomatoes.—Seed sown January 1 to 15; plants set in houses March 1 to 15; vines removed July 15 to August 1.

In plan 5, fall tomatoes sometimes replace the early crop of lettuce. Since tomato plants during early stages of growth do not fully occupy the space between the rows, quick-maturing crops such as radishes, lettuce, and beets for greens are sometimes planted between the rows. These are removed before the tomatoes require the space. Conditions best suited for the development of the tomatoes should be maintained, even though these conditions are not ideal for the interplanted companion crop. Proceeds from a companion crop often cover much of the cost of growing the tomato crop. However, many growers omit the companion crops and simply grow a spring and a fall crop of tomatoes as suggested in plan 2. This is the prevalent cropping plan used in Ohio.

SUITABLE SOILS AND THEIR MODIFICATION

Although greenhouse tomatoes grow well in many types of soils, loams to silt loams are favored over heavier or lighter soils. More labor is required in preparing and maintaining the heavy clay soils. These soils hold the soil water too tenaciously; thus, they tend to remain soggy or waterlogged and lack aeration. Sandy and gravelly soils are easily prepared but do not hold moisture and mineral fertilizing elements so well as heavier soils. The silt loams retain moisture well, yet water drains through them sufficiently, so there is good aeration.

Where the soil enclosed by the greenhouse is not suited to good plant growth or soil is needed for raised benches, an excellent soil may be prepared by composting fresh sod. Well-rotted manure equivalent to one-fourth the volume of the sod should be added. When manure is not available, muck, peat, or other organic material may be used to replace part or all the manure in composting greenhouse soil. The mixture of manure with muck usually gives better results than are obtained from the use of all muck or other materials. In the composting process where no manure is used, adequate quantities of a high-nitrogen chemical fertilizer should be mixed through the compost pile.

Manure or any of the above composted materials may also be used in houses where the soil is not changed. These materials lighten heavy soils and add organic matter and plant nutrients. When following such rotations as those suggested on page 4, organic matter and much of the nitrogenous fertilizer are applied before the other crops are planted. If composted material and nitrogen are added to the soil just before tomato plants are set, excessive vine growth and less fruit will result.

Greenhouse operators sometimes derive their supply of soil for benches and beds from land that had previously been sown to a cover crop. When the cover crop has matured it is skimmed off with some soil and composted. After the material is composted, it is moved into the greenhouse as needed.

A slightly acid soil, pH 6.0 to pH 6.5, is best. If lime must be added to correct too much acidity, the amounts to be used should be de-

termined by a careful soil test. Ground limestone, if needed, should be thoroughly worked into the soil during preparation for planting.

Preparing the Soil for Planting

Many of the larger greenhouse growers use power machinery to prepare the ground beds for planting because of the size of the operation and the prevailing high labor costs. Small tractors equipped with conventional tillage implements are mostly used.

Although rotary soil pulverizers do an excellent job of preparing a deep fluffy plant bed in one operation, the particles of some soils tend to cement together again after the plants have been set and the soil has been watered several times. This causes a shortage of oxygen and moisture available to the roots, as well as greater difficulty of root penetration. As a result many roots die, the plants are slowed in growth, and fruit yields are often reduced.

This unfavorable physical condition of the soil can be improved by incorporating an abundance of organic material through the greenhouse soil. These organic materials are often applied in summer just before planting the fall tomato crop rather than in the winter preceding the spring crop. Heavy soils require more organic matter than light ones to keep them loose and friable. Manure is applied in one application at the rate of 1,500 to 2,000 pounds or even more per 1,000 square feet. It is now common practice to use manure and mulches for tomato and cucumber crops and manure only for lettuce and radishes.

The ideal mulch should act as a ground cover during the growth of the tomato crop, then remain in the soil long enough to keep it in good tilth until the following crop is harvested. Wheat straw used to be the standard material for mulching. Other materials have been used—peanut hulls, crushed or shredded corncobs, oat straw, chaff, and old clover, alfalfa, or soybean hay. The mulching material is spread over the soil surface between the plants at the rate of 6 to 8 tons per acre or 300 to 400 pounds per 1,000 square feet. Under usual greenhouse conditions straw is decomposed quite rapidly by the organisms in the soil. These organisms draw heavily on the soil nitrogen supply during the process, thus robbing the growing tomatoes of their nitrogen which must be added as needed.

During decomposition of mulch material, readily available nitrogen fertilizers should be scattered over the material and watered into the soil before the plants show injury. The mulch prevents growth of weeds and hard packing of the soil between rows. It also promotes more even distribution of moisture by keeping the surface of the soil damp so the small feeding roots may grow and feed in the surface layer of soil.

Some experience and careful judgment are required in determining safe amounts of mulching and nitrogenous materials to be worked into the soil. Large amounts of "woody" mulching materials combined with nitrogen may, upon decomposition in the soil, release quantities of available nitrogen that are too high for best yields. Excessive amounts of available nitrogen in the soil cause rank growth and may interfere with fruit setting.

Chemical Fertilizers

In the early years of greenhouse vegetable culture little chemical fertilizer was used. Animal manure was then more plentiful, and

the growers depended on this source to supply the essential mineral elements. This source has become increasingly inadequate as the greenhouse tomato industry has expanded and the supply of animal manure around metropolitan areas has dwindled. Therefore the growers now must depend more and more on chemical fertilizers. They strive to provide enough fertilizer for their particular conditions so there will be a sufficient supply of plant nutrients to produce a maximum crop without carrying over excessive amounts of fertilizer from one crop to the next. In greenhouses this would lead to large excesses in the soil and interfere with tomato plant growth and fruiting.

One recommended schedule of fertilization for 1,000 square feet of soil bed is 25 to 30 pounds of 20 percent superphosphate and 20 to 25 pounds of sulfate of potash or muriate of potash. These fertilizers are broadcast and plowed in with the manure and mulch residues. The grower should apply nitrogen fertilizer only as it is needed by the developing tomato plants. Some growers tend to use too much nitrogen, causing the plants to grow too large and vegetative and causing a gradual increase in the residual amounts in the soil. This excessive carryover from crop to crop may be reduced before planting another crop of tomatoes by plowing into the soil several tons per acre of undecayed cellulose material, such as crushed corncobs or weathered sawdust.

Sodium nitrate and ammonium nitrate are two good sources of supplemental nitrogen for greenhouse tomatoes. Some growers find that monoammonium phosphate and ammonium sulfate are less favorable sources of nitrogen, because ammonia nitrogen tends to produce thin-leaved, tender plants in the spring crops that wilt easily on sunshiny days following cloudy weather. Plants so fertilized are also said to be more susceptible to injury by fumigation. Nitrate nitrogen, on the other hand, may produce thicker and darker green leaves.

Experienced operators learn to spot early symptoms of nitrogen deficiency. This is not entirely satistory because some reduction in yield is likely to result from waiting for deficiency symptoms. One helpful procedure is to have a soil test made in advance of planting by someone with sufficient experience to interpret the results correctly. In this way more definite information concerning the fertilizer requirements of a particular soil is obtained before planting the crop. Many State experiment stations provide such soil-testing service for residents of the State.

Some greenhouse tomato growers are now having chemical tests made of tomato leaf tissue to determine the fertilizer needs of the plants during the development of the crop. Many growers prefer to follow a schedule. The first application of nitrogen is made as soon as 3 fruit clusters have set on the plants. The number of supplemental feedings of nitrogen fertilizer will depend on the nature and amount of organic matter in the soil. Usually 2 to 3 applications of 6 to 7 pounds sodium nitrate or 3.5 pounds ammonium nitrate per 1,000 square feet of bed soil are made to the spring crop. For the fall crop usually 1 application is sufficient. The fertilizer is broadcast between the rows and watered in. Other essential elements are usually present in the soil in sufficient amounts. In some soils deficiencies may occur. Sometimes applications of mixtures of minor elements are made to avoid this possibility. These mixtures usually

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contain borax, manganese sulfate, zinc sulfate, and copper sulfate. Four ounces each of these compounds per 1,000 square feet are usually sufficient when applied to the soil. When applied as a leaf spray the total concentration of all chemicals in the spray solution should be reduced to ¾ percent or lower.

VARIETIES OF GREENHOUSE TOMATOES

The culture of hothouse tomatoes developed into a thriving industry in the British Isles long before it became a commercial enterprise in the United States. It is not surprising then that the small-fruited, free-setting, English-forcing varieties were largely used by greenhouse operators in this country when they started growing tomatoes. Carter's Sunrise, Sterling Castle, Comet, and Best of All were the most popular sorts in America. They are still grown to some extent in greenhouses, especially in the Eastern States.

These varieties, together with the varieties Potentate and Ailsa Craig developed later, have been used extensively as parents in breeding new American greenhouse varieties. The common characteristic of these European varieties is the large number of small 2- to 3-ounce fruits produced per cluster.

Market preferences greatly influence the choice of varieties grown in different regions. In the East the small 3- to 4-ounce red English-forcing types are still most popular. Indiana and Ohio prefer the larger fruited varieties weighing 6 to 8 ounces. Most Ohio growers prefer pink tomatoes, except in the southern part of the State. On the other hand, most of the Indiana greenhouse tomato growers produce red-fruited tomatoes; only around Terre Haute are pink tomatoes grown in large quantities. The north-central region favors red medium-small sorts averaging about 4 ounces.

Descriptions

Globe has been the most popular pink tomato for many years. It has been used in the Midwest, centered in the large commercial greenhouses of Ohio, more than any other variety. In 1930 a selection named Globe Strain A was introduced in Ohio for special greenhouse use. The plants have shorter internodes and larger leaves than the original Globe variety, and the fruits are more uniformly globular and smoother.

Globe Strain A was then crossed with a red wilt-resistant variety and from this cross was developed the pink-fruited, fusarium-wilt-resistant variety called Ohio Wilt Resistant Globe. These have become great favorites in the Ohio section. They are high yielding, have good size, ship well, and the dark-pink color distinguishes the product from the green-wrap southern field-grown tomatoes.

The southern Ohio greenhouse operators grow the standard red-fruited varieties Marglobe and Stokesdale more than any other varieties. Both varieties are tolerant of fusarium wilt.

Michigan State Forcing is the most widely grown greenhouse variety in Michigan. It was developed from a cross of Marglobe and Ailsa Craig. The red fruits are globe shaped, firm, and average 4 ounces. The variety is moderately resistant to fusarium wilt but is very susceptible to leaf mold.

Spartan Hybrid is the first hand-pollinated hybrid tomato introduced for greenhouse culture. It is a first-generation cross of Michigan State Forcing × Cooper's Special. Many greenhouse operators in the Grand Rapids area produce their

own seed. The red fruits are deep oblate in shape, not so firm as Michigan State Forcing, but tend to be more productive in cloudy weather. Fruit averages 4 to 5 ounces. This variety is not now grown so extensively as formerly, because of lack of firmness in the fruit.

Michigan-Ohio Hybrid, a cross of Michigan State Forcing and Wilt Resistant Globe, is assuming considerable importance in Michigan. The fruits are firmer and more uniform and the plants are more productive than Spartan Hybrid when grown during dark cloudy weather.

The English-forcing variety Potentate is very popular in Minnesota as a greenhouse variety. It is productive even in dark cloudy weather. The red fruits are firm and average 2 to 3 ounces in weight.

In the New England States and parts of New York the English-forcing varieties have been largely replaced by the varieties Waltham Forcing and Improved Bay State. Waltham Forcing is the most popular variety in this region for the spring crop and is used by many growers for both spring and fall crops. It was developed by selection from the variety Best of All. The 4-ounce fruits average larger than the parent variety and are very firm.

Improved Bay State is resistant to several races of leaf mold. The red fruits are deep oblate, smooth, and average 2½ to 4 ounces. It closely resembles the English-forcing type and is used by many Massachusetts growers to grow the greenhouse fall crop. It sets fruit well during dark cloudy autumn weather.

Waltham Hybrid is a new popular forcing variety in the Northeastern States. It is a cross of Waltham Forcing and Michigan State Forcing. The fruits are firm and average larger in size than Waltham Forcing.

Several wilt-resistant greenhouse forcing varieties have been developed in Illinois. These include Blair Forcing, Lloyd Forcing, Sureset Forcing, Urbana Forcing, and Long Calyx Forcing. They are all of the larger American-forcing type similar to but somewhat smaller than Globe, with the exception that Lloyd Forcing and Long Calyx Forcing are red fruited.

Another leaf-mold-resistant tomato—Waltham Mold-Proof Forcing—was introduced by the Waltham (Mass.) Field Station in 1952. It is said to be immune to all presently known races of leaf mold. It was developed from several crosses involving a wild Peruvianum hybrid with Prince Borghese and Pan America and Improved Bay State. The red fruits weigh 3 to 5 ounces.

The Indiana Agricultural Experiment Station has developed a new red-fruited greenhouse variety called Tippecanoe that possesses high resistance to fusarium wilt. It is similar to Spartan Hybrid, having resulted from a cross between a wilt-resistant Red Currant line and Michigan State Forcing. Tippecanoe is sensitive to overfertilization and overwatering but is much liked where wilt is prevalent.

GROWING TOMATO PLANTS FOR GREENHOUSE CROPS

It is an almost universal practice for greenhouse operators to grow their own tomato plants. This enables the grower to start his plants at the exact time so they will be at the right stage of development when he wishes to plant the crop. He is assured of a supply of stocky plants of the desired age and variety, and the plants can be transferred to the permanent beds with the least shock.

Providing Sufficient Seed and Plants

An ounce of fresh, well-matured tomato seed should contain at least 8,000 seeds. This should be sufficient to produce 3,000 to 5,000 strong, healthy plants. The grower should use the best seed obtainable, since the total cost of seed is relatively insignificant as compared with the large investment in equipment and in growing the crop. It is good insurance to grow more plants than will be needed to set the available bed space.

About 225 plants are required to set 1,000 square feet of bed, allowing between 4 and 4½ square feet of growing space per plant, which is the amount of space commonly provided by tomato greenhouse operators.

The plants may be spaced 15 to 24 inches apart with the rows further apart as the space between plants is reduced. As an example, plants set 18 inches apart in rows 3 feet apart have 4½ square feet of growing room while plants set 15 inches apart in 3½-foot rows have a little less, about 4⅓ square feet of growing space.

Time for Sowing Seed

The date for sowing the seed should be governed by the desired time for the first harvest. About 4½ months should be allowed for a fall crop and about 5½ months for a spring crop. Plants grown in summer and early fall develop faster than those grown in late-fall and early-winter months. Unless other crops in a rotation interfere, the tendency is to plant the fall crop earlier than formerly. Increased demands for greenhouse tomatoes immediately after the outside crop has been killed by frosts and the difficulty of obtaining a good set of fruit after the prevailing cloudy weather that comes in November make earlier fall plantings profitable. Moreover, it takes 50 to 60 days to develop tomatoes from blossoms to full ripeness under late-fall and winter conditions, so that if the tomato plants are to be removed by mid-January, the fruit must be all set by mid-November.

Greenhouse growers vary the time of sowing the seed for the early-spring crop so as to fit it into diverse cropping systems. Since the trend is toward a longer tomato growing season, the seed is being sown earlier than formerly. Controlled experiments have shown that earlier planting not only produces the largest yields but also usually brings better prices on the early-spring market. Some Ohio growers with large acreages sow the seed for the spring crop as early as October 25. These plants are set in permanent ground beds about January 10 and the harvest begins around the first of April.

Methods Used for Starting the Seedlings

Most tomato seedlings for the greenhouse crop are started in steamed soil mixtures of various compositions—one-half composted soil and one-half vermiculite; one-half humus or weathered muck and one-half fine sand; or a loam soil well supplied with organic matter.

Flats filled with the soil mixture for seed germination are usually steamed at 10 to 15 pounds' pressure for about 3 hours. They are then allowed to stand, preferably for a week or more, before the seed is sown.

The seed is usually sown in drills scant ½-inch in depth and 2 to 3 inches apart (fig. 2). A wooden lath so notched that it will make a drill of proper uniform depth is pressed into the screened soil mixture to make the rows. The seed should be distributed uniformly, 4 to 6 seeds per inch, in the rows,

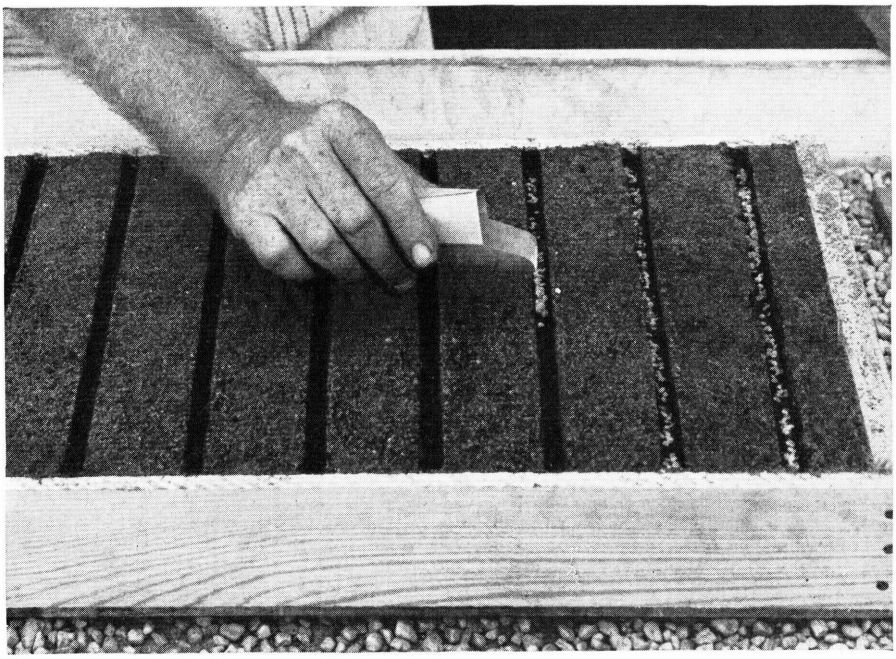

FIGURE 2.—*Sowing tomato seeds in a flat, a method commonly used for starting greenhouse tomatoes.*

which are then filled level full with the germinating medium to cover the seeds.

To insure good germination of the seed it is important to keep the soil around the seed moist until after the seeds have sprouted. After germination the surface soil should be wet no oftener than necessary to keep the young plants growing. Some growers hasten germination by setting the seed flats over the greenhouse heating mains. Temperatures ranging from 70° to 80° F. are satisfactory during this period. After germination is completed it is best to reduce the temperature range to 60° to 70° in order to promote stocky growth of the seedlings.

Growing the Planting Stock

Young seedlings should be transplanted as soon as their stems have straightened and the seed leaves (cotyledons) have opened horizontally, which is usually 9 to 14 days after sowing the seed. The younger the seedlings can be transplanted, the quicker they recover from the shock. When transplanting young tomato seedlings, the grower should always grasp the plant by one of the seed leaves. A little pressure on the stems can easily injure the seedlings permanently. It should also be a routine practice for all persons to wash the hands in strong soap and water before handling young tomato plants to avoid infecting them with mosaic viruses. None of the workers should be allowed to use tobacco in any form while working around the plants. After one has smoked or otherwise handled tobacco, he should always wash his hands again as directed above before starting back to work.

One of the most satisfactory

FIGURE 3.—*Sturdy tomato plants spotted in a deep flat in first bud stage ready for planting.*

methods now used is direct transfer of seedlings from the germination flat to 4- or 5-inch clay pots where they grow until ready to plant. Sometimes the seedlings are spotted about 4 by 4 inches apart in deep flats (fig. 3). Experiments have shown, however, that the pot-grown plants usually start growing sooner and produce ripe fruit 7 to 10 days earlier than the plants grown by other methods.

Since the plants for the spring crop must be grown during the period of the shortest and cloudiest days of the year, it is most important to provide the best possible conditions for their proper development. The potting soil in which the plants are to be grown should be a well-aerated sandy loam that is high in phosphate and potash but is low in nitrate nitrogen.

High nitrate content of the soil with abundant moisture during short days will cause the plants to grow soft and spindling. Under these conditions the first flower buds often fail to develop properly and produce no good pollen. They usually drop off and delay fruit setting for weeks. When grown slowly in soil low in available nitrogen with moderate soil moisture the plants will grow into a fruitful condition during the winter. In regions where the smaller English-type forcing tomatoes are commonly grown, it is not necessary to keep the available nitrogen in the soil at such a low level. These varieties set fruit quite readily even when the days are short and there is considerable cloudy weather. The blossoms of these varieties very seldom drop off even though not pollinated. Where more nitrogen can be made available during this period the plants develop faster and mature more quickly.

The night temperature should be kept as close to 60° F. as is practical, with day temperatures maintained between 65° to 70° F.

In 8 to 10 weeks from seed germination these plants should be 8 to 10

inches tall with strong roots and with the first fruit buds partially developed (fig. 4). They will be

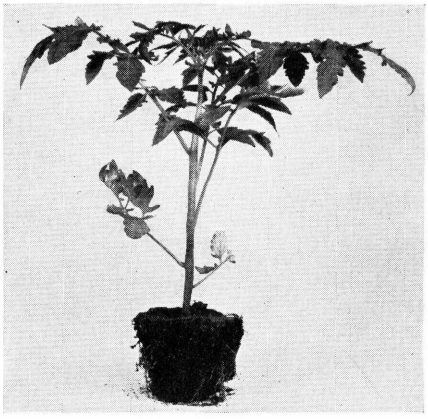

FIGURE 4.—*A good tomato plant grown in 5-inch clay pot, ready for setting in greenhouse bed.*

somewhat deficient in nitrogen as indicated by the light yellow-green color of leaves and by the purple tinge of stems and petioles. The plants at this stage should be firm but not hard and woody. This is the best time to set the plants in the ground beds. If they are held much longer the root systems will become potbound and stunting of the plant growth will occur.

If the plants should become too hardened before transplanting, an ounce of sodium or ammonium nitrate per gallon of water will stimulate renewed growth. Complete all-soluble starter fertilizers are now available. These furnish the plants better balanced nutrition. A good starter solution may be made by dissolving 3 pounds of 10–52–17 fertilizer in 50 gallons of water. A half pint of this solution per plant is usually ample to stimulate renewed growth of the plants. It is best to pour the fertilizer solution directly into each pot a day or two before the plants are to be transplanted out in the greenhouse beds. The starter fertilizer will give the plants a quicker start, thus hastening the first harvest.

During the entire plant-growing period, the utmost care should be exercised to avoid infecting the plants with tomato mosaic virus. Whenever it is necessary to handle the plants in any manner, the workers should be instructed to wash the hands and contaminated clothing and tools with strong laundry soap and water before touching the plants.

When and How To Set Plants

About March 1 used to be a favorite date for setting out the plants for the spring crop in the greenhouse. This avoided much of the coldest winter weather and thereby saved large quantities of fuel. But development of modern greenhouses has enabled operators to plant at earlier dates so the harvest season can begin 6 weeks earlier, thus extending the harvesting season for a longer period. Some growers set the spring crop regularly about January 10; harvest begins around April 1 and closes from July 1 to August 15.

Houses should be warmed thoroughly before the plants are set during winter weather. In order to insure prompt growth of plants some growers introduce steam into the tile used for steaming the soil for a short time until the soil temperature is raised to 70° F. Many growers are now giving their soils a complete steaming before each tomato crop and setting the plants as soon as the soil temperature has dropped to 70° to 80°. Tomatoes should never be planted until the soil has cooled to 80° or lower.

Warmed water is also used sometimes at transplanting time to help the plants to a quicker start. A word of caution should be added here. If soft vegetative plants have

to be used for winter planting, starter fertilizers and extra heat should be omitted.

When plants are grown in summer for early-fall planting the days are long and usually bright. These conditions encourage high carbohydrate (sugar, starch, and cellulose) production, and hence the plants use larger amounts of nitrogen during summer. The plants tend to become nitrogen starved, so more nitrates must be supplied to maintain good growth.

On the other hand, when the plants are being grown in the short days and prevailing poor light of winter, much smaller amounts of carbohydrates are produced. In order to obtain normal growth and fruiting of tomato plants there must be maintained a proportional balance between the amount of nitrogen available to the tomato plants and the rate of carbohydrate manufactured in these plants. Therefore, during the months of limited carbohydrate production, available nitrates must be kept low until after some fruit clusters have set on the plants.

To be successful a tomato grower must learn to recognize this growth relationship and to know what to do to keep the carbohydrate-nitrogen ratio in proper proportion.

After fertilizers and organic supplements have been plowed under and the steaming is done, the soil should be given a final surface working just before the plants are set. This cultivation provides soil aeration, which stimulates reinoculation of the soil-nitrifying organisms and reduces the chances of steaming injury.

The beds are usually laid off with a marker or with a line. In large houses furrows about 6 inches deep are often made with a light tractor. The sequence of planting operations is varied according to the grower's plans. Many growers set the plants directly in place, but when the soil is to be covered with a mulch it is sometimes spread evenly over the beds before setting the plants. The pot-grown plants may then be set in place on top of the mulch and left a week or two longer to reach the right bud stage before setting in the ground bed.

It is very important, except when growing free-setting forcing varieties, to have the first bud cluster at the proper stage of development before planting so the blossoms will open normally and set fruit. The grower must not allow the plants to take root in the soil beneath them while they are sitting on the mulch. If the roots are allowed to penetrate into the bed soil the nitrogen and moisture available very probably will cause the plants to become succulent and vegetative, leading to failure to develop normal blossoms.

Most growers water the potted plants thoroughly the day before they are to be planted in the permanent beds. The plants are then easily removed without disturbing the rootlets in the soil by inverting the plant and jarring it out of the pot. The plants are set in holes dug deep enough in the bed so that the soil from the pot is covered with an inch or more of soil when the hole is filled. After all plants have been set the mulching material should be leveled around the plants and the plants should be watered. Only enough water should be used to settle the moist soil around the roots and to provide sufficient water for good growth—about a quart per plant.

Growers should always remember that tomato plants are to be handled as little as possible throughout their development to avoid so far as possible the spreading of virus diseases through the plants. When they must be handled, the operator's hands, clothing, and tools should be washed free of any possible virus

contamination before touching any tomato plants. Also, the operator should not smoke while in the greenhouse.

IMPORTANCE OF CONTROL OF SOIL MOISTURE

Too much water may ruin the crop when the plants are first set out. Later in the season when the plants have matured and are laden with growing fruit much more water is required by each plant, so overwatering is quite unlikely. Too much soil moisture in January and February during cloudy periods tends to promote vegetative growth at the expense of fruitfulness. Many growers water with hose for 4 to 6 weeks after setting the plants or until after the first clusters of fruit have begun to enlarge, taking care to wet the soil just down to the root zone. Until after the second or third fruit clusters have set, some growers prefer to water the spring crop only where plants show signs of wilting. Sometimes the spring crop will grow for 6 weeks or longer with only spot watering before a general watering becomes necessary.

The frequency of watering during this period will depend mainly upon the amount of sunlight and the structure of the soil. As the season advances the lengthening days and more intense sunlight promote more normal flowers with abundant pollen and faster fruit development. By midseason watering is done about once or twice a week and 1 to 1½ acre-inches equivalent of water is applied each time in order to satisfy the needs of the crop.

In the larger greenhouses when the water requirements of the crop become large, the water is applied through overhead irrigation pipes, longitudinal sprinkling pipes with nozzles that throw horizontal streams of water close to the soil, or through subirrigation tile. Growers prefer to do most of the required watering early in the day. Operators should use a soil auger or spade frequently to check the moisture content of the soil. They should learn to know the moisture content of their particular soil by its appearance and by squeezing it in the hand.

MAINTAINING PROPER TEMPERATURE RANGE AND VENTILATION

The regulation of greenhouse temperature is second only in importance to providing the optimum amounts of water for the plants. While the crop is growing the temperature should be held between 60° to 65° F. during the night and between 70° to 75° during the day if the sun is shining. The temperature may at times range as high as 80° on clear days without adversely affecting the development of the crop. On cloudy days the temperature should be kept around 65° to 68°. When this temperature schedule is maintained, the fruit buds should develop normally and the fruits should be smooth and of high quality. In no case should the night temperature be held below 58° during fruit bud development, as this may cause poorly formed blossoms that usually abort, or if they set fruit at all the tomatoes will be misshapen and of poor quality.

Ventilation of the tomato greenhouse is essential in removing excess heat and humidity and in bringing in fresh supplies of air. Heating and ventilation should be so regulated as to keep the atmosphere of the house in circulation. Moisture constantly evaporating from the soil surface and transpiring from the tomato foliage tends to build up humidity.

Outside air may enter the greenhouse through opened side ventilators and be warmed as it moves through the greenhouse, picking up excess moisture and carrying it out through the top ventilators. This is especially helpful in the fall and spring seasons to help control leaf mold.

The relative humidity inside the greenhouses should be kept below 90 percent constantly, in order to keep under control the leaf mold disease that is so destructive to greenhouse tomato plants. If the humidity of the house is allowed to go over 90 percent for 1 day, leaf mold infections may result.

No rigid rules can be laid down for ventilating. Usually the ventilators are closed at night during cold weather when some heat must be kept on in the houses. Even then, it may be necessary to "crack" (slightly raise) the top ventilators to maintain enough exchange of air to prevent the humidity from building up above 90 percent.

The most dangerous times are during relatively mild weather in fall and spring when proper night temperature may be maintained without any heat in the greenhouse by keeping the ventilators closed. This is likely to create a combination of conditions inside the houses that will start an epidemic of leaf mold raging through the plants. No grower should ever be tempted at such times to save the small amount of fuel needed to provide a little heat and sufficient ventilation in the houses.

Major heat regulation is accomplished by opening and closing the valves of the heating lines. Hourly adjustments are usually made by regulating the ventilators. On clear days the direct rays of the sun raise the temperature inside glasshouses very rapidly when the ventilators are closed. After sunrise when the temperature of the houses reaches 70° to 72° F., the ventilators should be raised to let in fresh air and to allow escape of moisture-laden air. It may also be necessary to close part or all of the valves controlling the flow of heat to keep the temperature from rising much higher.

CULTIVATION

It is not usually necessary to cultivate where the soil was steamed before the crop was planted, except to loosen up the surface soil where it has become packed down from walking over it. When the soil is covered with a mulch, cultivation is unnecessary.

In houses where neither steaming nor mulching of the soil is practiced some cultivation will have to be done. Hand cultivators and hoes are satisfactory for small operations, but garden tractors designed to cultivate between the rows and between cross-checked plants are best for large greenhouse operations. Cultivation should always be shallow—just enough to break up the surface crust and destroy any weeds that may have started to grow. The tomato feeding roots, close below the soil surface, should be disturbed as little as possible. Breaking up the surface crust helps the irrigation water to soak into the soil evenly where it is applied.

TRAINING AND PRUNING

The single-stem system of pruning and training is almost universally used by greenhouse growers, although a few operators train the plants to two and sometimes three stems (fig. 5). The small shoots that would develop into lateral branches should be removed about once a week. These lateral buds appear at the point where the leaf stem joins the main stem. The fruitbud clusters appear on the opposite side of the main stem, usually

FIGURE 5.—*Tomato plants, supported on slender wood stakes, growing in a small greenhouse unit.*

above or below the points where the leaves are attached.

The lateral shoots should be removed while they are still small and can be easily removed without making large wounds. It is best to break the shoots off rather than to cut them; viruses are readily spread from plant to plant by all pruning tools unless sterilized after each plant operation. The shoot to be removed should be grasped with thumb and forefinger and bent over sharply to one side, then snapped

off with a sharp bend and pulled in the opposite direction. This reversal of direction of breaking stress on the leaf axil shoot becomes increasingly important when the shoot is large, so as to avoid injuring the leaf axil or the bark of the main stem. This method of removing plant parts also helps to prevent the spread of diseases, particularly mosaic and related virus diseases. A few growers are also using a square of paper tissue for each plant so the operator's fingers do not directly contact any part of the plant. The tissue is discarded and a new square is taken before operating on the next plant.

In all training and pruning the grower should remember that all organic food for fruit development must come from the leaves. To yield well, the plants need a maximum of functioning leaf surface. Some growers provide additional leaf surface for each plant by allowing the axillary shoots that are immediately below each blossom cluster to grow until they have developed their first two leaves. The portion above the two leaves is then removed.

After the lower clusters of fruits are approaching maturity it may sometimes be desirable to prune off part of the lower leaves if they are yellowing. This will provide better air circulation and will permit better distribution of irrigation water. It makes easier harvesting of the lower fruit clusters and helps in the control of leaf mold.

Most greenhouse tomato plants are supported by stout wires running parallel to the soil surface 6 or more feet above it. These wires are directly over the plants and are attached to the greenhouse frame. The most commonly used support for each plant is a strong string or sisal twine tied to the wire directly above the plant with the other end tied loosely around the stem of the plant near the ground (fig. 6). After allowing the plant to grow for some distance above the tie it is wound loosely around the string, always in the same direction. While this is being done, the string should be kept under the point of leaf attachment to the main stem. In this way the leaves will not be broken and the plant will be supported at the bases of the leaf petioles and will not slip down the string. The tender growing tops with developing leaves are left to grow free for awhile, as they are likely to snap off if wound around the string all the way to the top of the plant. Sometimes the lower end of the string is tied to a coil wire anchor or to a peg driven in the soil near the base of each plant. When the plants are laden with exceptionally heavy yields of fruit it may be advisable to support the upper portion of such plants with extra string attached to the overhead wire to prevent breakage of supporting string and consequent loss of productive plants.

Light stakes may sometimes be used to support tomato plants. They are pushed into the soil near the base of each plant and tied at the top to small wires overhead. In supporting the plant on the stake, the best practice is to tie raffia or soft twine tightly around the stake 2 to 3 inches above a leaf petiole or fruit cluster, then loop the raffia under the base of petiole or fruit cluster, take up most of the slack, and tie a square knot.

POLLINATION

Although tomato plants are normally self-fertilized when grown in fields and gardens, some pollination of greenhouse tomatoes is usually necessary in order to obtain a good yield of fruit. The natural air currents outdoors insure sufficient movement of tomato flowers to dis-

FIGURE 6.—*Fruiting greenhouse tomato plants trained to single stems and supported on sisal twine.*

lodge the pollen and insure its even distribution over the stigmatic surface. Satisfactory crops of free-setting tomato varieties are also grown in greenhouses without any assistance to natural pollination. However, most of the greenhouse crops grown in the United States require some method of jarring the flowers, or of transferring the pollen by hand in order to obtain an adequate set of fruit.

Mechanical Methods

Pollination should commence just as soon as the first flowers are fully opened and should continue until all the fruit the grower desires have been set. The operation should be done regularly, preferably between 9 and 3 o'clock each day. Pollination is especially important in late fall and winter when the days are short.

Best yields of high-quality fruit are obtained by hand-pollinating each flower. This is costly and timeconsuming, however, so hand-pollinating is impractical on a large commercial scale. The most efficient method of pollinating the first flower clusters of the spring crop and the late flower clusters of the fall crop seems to be the electric vibrator, which operates on an ordinary dry-cell battery. This vibrates a wire loop covered with rubberlike material (fig. 7). The loop is moved from contact to contact with each cluster as rapidly as the operator can do it. Every flower is shaken several times and many pollen grains contact the stigmatic surfaces of the blossoms.

The general shape, size, and smoothness of each tomato fruit is largely determined by the thoroughness of pollination. Since a single pollen grain is required to fertilize each seed, it takes many of them to fertilize each fruit. If the seeds are all fertilized the tomato will enlarge uniformly, but if not the fruit is likely to be only partially developed and to be misshapen. This is a common cause of low-grade fruit.

Tomato fruits usually set without much difficulty on the first blossom

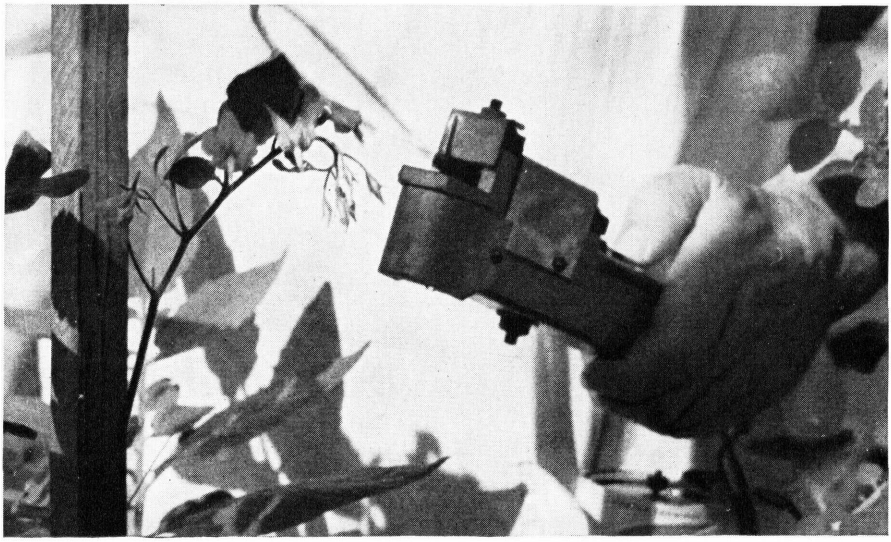

FIGURE 7.—*Pollinating tomato flowers with an electric vibrator.*

clusters of the fall crop and the later blossom clusters of the spring crop. Under these circumstances simpler methods of assisting flower fertilization are very satisfactory. One method commonly used is to have an operator walk between plant rows, tapping each overhead wire sharply with a stick. The vibrations tend to travel along each wire in both directions so the flowers of plants in adjoining rows are also jarred. Thus, the blossoms of all plants are repeatedly shaken as the operator taps each wire again when he walks through between the next two rows of plants. Some growers prefer to jar each plant directly by tapping it with a rubber-covered stick. This method is effective, but there is more danger of bruising the plants or the growing fruits.

The amount of time necessary to develop a tomato from a fertilized flower to a ripe fruit varies with the season. In winter it usually takes about 60 days; in early spring about 55 days; in June 40 to 45 days.

Sometimes, when it is desirable to terminate the harvest of a tomato crop at a definite time, the vines are topped by the removal of the growing tips as soon as the plants have set all the fruit that can mature within the specified time. This allows all the food that will be manufactured by the plants to be used for the development of the fruits already growing on the plants.

Chemical Treatments

Greenhouse tomato plants grown in northern latitudes during the season of short days and prevailing cloudy weather are sometimes stimulated to set fruit by applying hormonelike chemicals to the flower clusters. None of these chemicals should be used as a substitute for pollination. They should be used only to supplement pollination when greenhouse conditions are too adverse for pollination alone to be effective in setting the fruit.

The flower clusters should be sprayed with the chemical hormone only after several of the flowers have opened. Investigators have observed that treating the immature flowers resulted in a poor set of relatively small-sized fruit. In the bud stage of a flower both the pollen and the ovules are adversely affected. When applying the chemical, the spray should be directed so as to avoid as much as possible spraying the immature terminal vegetative parts of the plant, which tend to develop abnormally when thus treated. Hormone treatments are most satisfactory when applied to the face of the flower.

Only a few of the many compounds that are known to stimulate fruit setting are satisfactory as sprays for commercial use. The chemicals that have been most widely used to stimulate tomato fruit setting successfully are para-chlorophenoxyacetic acid, alpha-orthochlorophenoxy-propionic acid, and indole-butyric acid. They are sold under several trade names. The recommended dosage for the first-mentioned compound is 25 to 30 parts per million and for the others 75 to 100 parts per million.

The fruits of certain varieties set by chemical treatments grow soft and do not keep well. Buyers can distinguish treated fruits from those untreated by the remains of the blossom caught under the sepals of the treated fruits, and they are apt to discriminate against them. The very firm smaller fruited varieties, as grown in the northeast and north-central regions, seem to be less subject to softening by treatment with hormonelike chemicals, and the treated fruits are marketed satisfactorily.

DISEASES

In the greenhouse the control of disease is essential to profitable tomato production and requires constant watchfulness. Because of the close spacing and frequent handling of the plants, the opportunities for the spread of disease-producing fungi, bacteria, and viruses are somewhat greater than with tomatoes in the field. On the other hand, soil sterilization and some control of temperature and humidity afford means of disease prevention and control that are not available when plants are grown out of doors.

Diseases such as fusarium wilt, verticillium wilt, leaf mold, mosaic, and root knot occur so frequently that regular practices of sanitation are needed to prevent serious losses. These measures are of value also in reducing losses from diseases such as stem rot, botrytis rot, streak, spotted wilt, and late blight that occur less frequently but occasionally cause severe damage. Good cultural practices will usually prevent serious losses from nonparasitic diseases such as blossom-end rot and pockets. All these diseases and others that affect tomatoes are fully described in Farmers' Bulletin 1934, Tomato Diseases.

NEMATODE INJURY [3]

Tomatoes are subject to the attacks of various nematodes, or eelworms. These are minute, usually eel-shaped organisms not visible to the naked eye. Various kinds live by the millions in the croplands of the United States. Many attack plants. They are brought into the greenhouse in the soil or with infected plant roots.

In this country the roots of the tomato plant may be attacked by the kinds that live within the roots, such as the root-knot nematodes [4] and meadow nematodes; [5] or by the kinds that feed on the plant but do not entirely enter the roots, such as the spiral nematodes [5] and stubby-root nematodes.[5] The root-knot nematodes, however, appear to cause the most damage. They occur in many home gardens in most of the States, and in greenhouses anywhere. They are often the cause of significant losses indoors and outdoors in commercial tomato plantings.

Any eelworm damage on tomato plants is difficult to recognize, because nematodes do not produce specific aboveground symptoms. Tardy growth, unhealthy appearance, wilting during the hot part of the day or during dry weather, or yellowing and stunting of the whole plant may indicate the presence of large numbers of nematodes on the roots. Roots of plants suspected of being infected with nematodes should be examined. When numerous, such nematodes as the spiral, meadow, or stubby-root nematodes may produce stunted, short, or sloughed-off roots.

The root-knot nematodes are the easiest to recognize. They induce the formation of galls, irregular knots, and swellings of the roots. On the tomato plant these galls may be small and hardly noticeable or large and irregular, as shown in figure 8. Single females or groups of them may be found inside these galls. They appear as pear-shaped whitish bodies just barely visible to the naked eye, measuring only about one-thirtieth of an inch in diameter. A single root may con-

[3] Prepared by Edna M. Buhrer, associate nematologist, Horticultural Crops Research Branch.

[4] *Meloidogyne* spp., formerly called *Heterodera marioni* (Cornu) Goodey, but now know to comprise a group of many species.

[5] Meadow nematodes=*Pratylenchus* spp.; spiral nematodes=*Helicotylenchus* spp. and *Rotylenchus* spp.; stubby-root nematodes=*Trichodorus* spp.

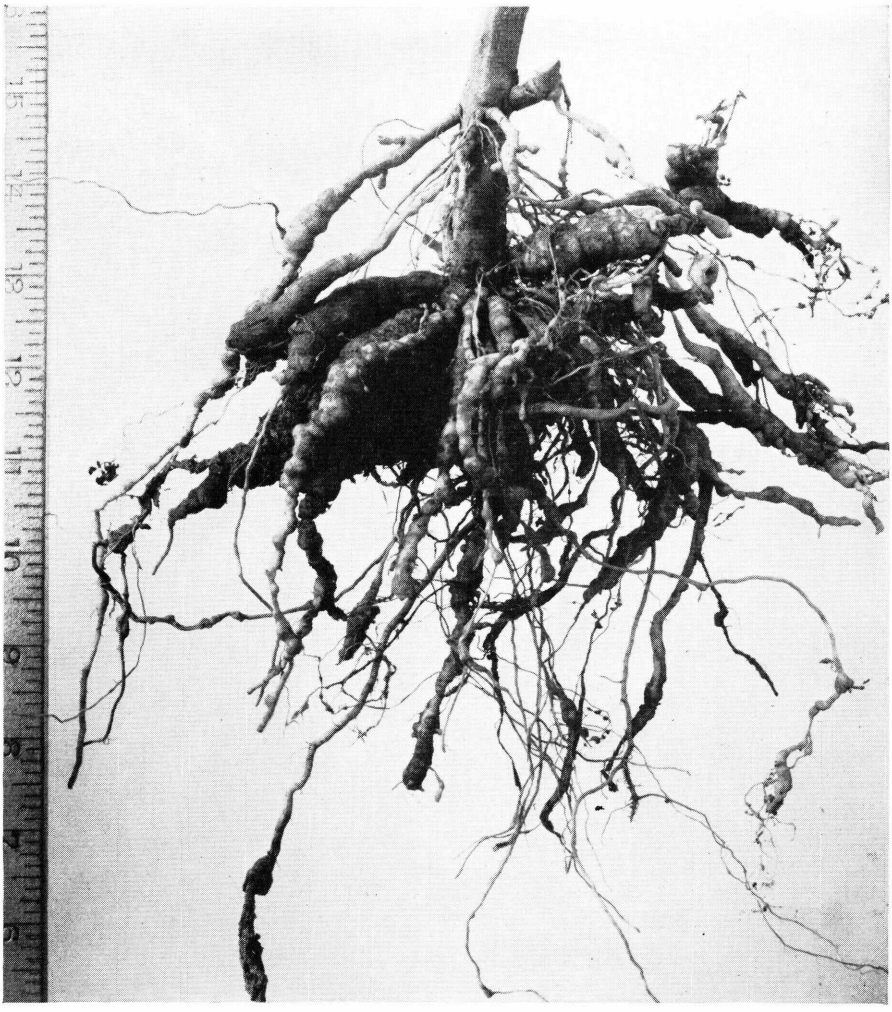

FIGURE 8.—*Tomato plant infected with root-knot nematodes.*

tain several hundred of such females, each capable of producing 500 eggs or even more within the span of 2 to 3 months. During the growing season the eggs usually hatch in a short time and the eel-shaped larvae then make their way through the soil and enter new roots. There they may grow to maturity and in time produce eggs. At a temperature near 80° F. this will take about 25 days, while at 62° it takes approximately 87 days; below 55° the root-knot nematodes stop their activity. Even if roots of a suitable host plant are not available or if conditions are otherwise not proper for the development of this group of nematodes, there is still danger of carrying the disease in the soil for at least 2 years.

Seedlings and young tomato plants suffer much more from nematode attacks than older plants. It is, therefore, essential to protect

such plants from invasions. After long feeder roots have been developed, attacks by nematodes cause much less damage.

Recommendations for Control

Light sandy soils are preferred by nematodes. Heavy soils also may be infested, but in these the spread is much slower. Eelworm pests once established in a soil are difficult to eradicate; therefore, every effort should be made to prevent their introduction and establishment in the greenhouse. Unfortunately man himself is the most effective distributor by transfer of infected root crops and seedlings and by unclean implements. It is important, therefore, to examine carefully the roots of tomato seedlings and transplants. Discard and destroy plants with decaying and diseased roots, particularly those that have galls and swellings. To produce clean tomato seedlings, it is best to grow them in steam-sterilized soil, in soil treated with a fumigant, in vermiculite, or in peat moss.

If tomatoes have to be planted in soil known to be infested with root-knot or other nematode pests, treatment with steam or with one of the newer soil fumigants is strongly recommended. Properly done, such treatments should result in better growth, better stands, and increased yields that give returns well above the cost. Steam sterilization of the soil, as practiced in greenhouses equipped with the necessary apparatus, will serve to control nematode pests. In the absence of steam apparatus, the grower should use chemical fumigants applied to the soil before the tomatoes are planted. All of the soil fumigants, through volatilization or chemical reaction, give off toxic fumes that diffuse through the soil and control the nematode pests. An interval of time, ranging from 5 to 15 days, must elapse between application and planting to allow time for the chemicals to lose their toxic properties and for the fumes to escape into the air.

The fumigants most commonly used in greenhouses are mixtures containing methyl bromide, chlorobromopropene, or chloropicrin. These will control certain other soil pests and diseases as well as nematodes. Other soil fumigants more specifically used for control of nematodes are mixtures containing dichloropropene and those containing ethylene dibromide.

All these fumigants, except those containing methyl bromide, are liquids. They are applied by injection into the soil at closely spaced intervals. For small quantities of soil no special apparatus for applying the chemicals is required; for larger quantities, such as ground beds, a hand applicator is advisable, to deliver the correct amount of chemical per injection. Methyl bromide is applied as a gas by releasing it under a gastight cover.

Further details of application procedures for soil fumigants and precautions on their use are best obtained from manufacturers and distributors of the fumigants, from State agricultural experiment stations, or from the United States Department of Agriculture.

INSECTS AND OTHER PESTS

The most common pests of greenhouse tomatoes are the greenhouse whitefly, aphids (plant lice), spider mites, thrips, the garden centipede, and the corn earworm. Others that occasionally cause severe damage include mealybugs, the tomato pinworm, the tomato russet mite, the armyworm, cutworms, the cabbage looper, and the greenhouse leaf tier.[6]

[6] For the scientific names of these insects see table 2, p. 25.

TABLE 2.—*Pests of greenhouse tomatoes and the effective organic insecticides*

[See text for specific control of each pest and p. 28 for precaution]

Pest	TEPP	Sulfotepp	Malathion	Parathion	DDT	Lindane
Armyworm (*Cirphis unipuncta* (Haw.))			X	X	X	
Banded greenhouse thrips (*Hercinothrips femoralis* (Reut.))	X	X	X	X	X	
Black cutworm (*Agrotis ypsilon* (Rott.))				X		
Cabbage looper (*Trichoplusia ni* (Hbn.))				X	X	
Citrus mealybug (*Pseudococcus citri* (Risso))	X	X	X	X		
Corn earworm (*Heliothis armigera* (Hbn.))				X	X	
Foxglove aphid (*Myzus solani* (Kltb.))	X	X	X	X		
Garden centipede (*Scutigerella immaculata* (Newp.))						X
Grape mealybug (*Pseudococcus maritimus* (Ehrh.))	X	X	X	X		
Greenhouse leaf tier (*Phlyctaenia rubigalis* (Guen.))				X	X	
Greenhouse whitefly (*Trialeurodes vaporariorum* (Westw.))	X	X	X	X		
Green peach aphid (*Myzus persicae* (Sulz.))	X	X	X	X		
Onion thrips (*Thrips tabaci* Lind.)	X	X	X	X	X	
Potato aphid (*Macrosiphum solanifolii* (Ashm.))	X	X	X	X		
Tomato pinworm (*Keiferia lycopersicella* (Busck))				X	X	
Tomato russet mite (*Vasates lycopersici* (Massee))				X		
Two-spotted spider mite (*Tetranychus bimaculatus* (Harvey))	X	X	X	X		

For control of pests on tomatoes in commercial greenhouses, the new aerosol treatments have almost entirely replaced the older treatments, such as fumigating with calcium cyanide or with nicotine on steam pipes or in combustible powders, or spraying with rotenone, arsenicals, or thiocyanates.

Aerosols are available commercially and are accompanied with full directions for use in the greenhouse and with precautions for protection of the operator. The 10-percent parathion aerosol is the one most widely used on tomatoes. Two or three applications on the young plants in the pots and another as the first blossom clusters form usually control all insects and related pests until the crop is harvested. Other aerosols that are effective against certain pests include 5-percent DDT, 5-percent TEPP, 5-percent sulfotepp, and 10-percent malathion (table 2).

All these aerosols are applied in the air above the plants at the rate of 1 pound per 50,000 cubic feet. The applicators usually deliver the material at a rate to treat 1,000 cubic feet in 4 seconds. The foliage should be dry, and the greenhouse temperature should be held between 70° and 85° F. The ventilators should be closed for at least 2 hours after application, or overnight if feasible, and then opened for thorough ventilation before anyone is allowed to work in the house.

Greenhouse Whitefly

When whiteflies are present, they fly about like snowflakes when the foliage is disturbed. They are triangular in shape. The immature insects resemble small scales attached to the leaves. Heavy infestations cause yellowing of foliage and excessive deposits of sticky honeydew on fruits and foliage. A black fungus often grows on the honeydew.

TEPP and sulfotepp aerosols will kill the adults but not the early stages of the fly. Applications must be repeated 4 or 5 times at 5-day intervals. Two applications of malathion or parathion 2 weeks apart will keep this pest in check, as residues of these materials kill many adults emerging from immature whiteflies.

Aphids

At least three kinds of aphids attack greenhouse tomatoes. The foxglove aphid, recognized by its shining pale-green body with two dark-green areas on the abdomen, causes yellow spotting and distortion of tomato leaves. The potato aphid, a frosty pink or green species, feeds on the young tips and blossom clusters. The green peach aphid, a small, greasy-green species, feeds on the underside of the leaves. In addition to their feeding injury the aphids may transmit mosaic diseases.

A single application of an aerosol containing TEPP, sulfotepp, malathion, or parathion is effective against aphids.

Two-Spotted Spider Mite

The two-spotted spider mite, also known as the red spider, varies in color from pale yellow to red with two dark spots. The microscopic mites remove the cell contents of green leaves, giving them a stippled or bronzed appearance and stunting their growth. Severe injury is accompanied by webbing of foliage. Spring crops of tomatoes are usually more severely infested when preceded by a fall crop in the same greenhouse.

TEPP, sulfotepp, and malathion are effective against spider mites, but parathion aerosol is the most widely used remedy in commercial greenhouses. Two applications at 10- to 14-day intervals, as directed, are necessary to control an established infestation.

Thrips

The onion thrips, a small, light-brown, slender insect, enters the greenhouse during the outdoor growing season. Leaves upon which this thrips feeds show white stippled areas, and when extensively injured they turn brown and die. This thrips may also transmit the spotted wilt virus from dahlia or other host to tomato.

The banded greenhouse thrips does not survive outdoors in the Northern States. It is usually brought into vegetable greenhouses on house plants or other ornamentals.

DDT, parathion, and malathion aerosols are very toxic to thrips. Usually 2 or 3 applications at 10-day intervals are required. A 3-percent DDT dust is also effective.

Garden Centipede

Garden centipedes are present in most greenhouses. The milky-white creatures, about ¼ inch long with 12 pairs of legs, quickly disappear after they are exposed by turning over the soil. In loose soil high in organic matter they become abundant and destroy the young roots and stunt newly set plants.

If the soil is kept moist to induce the centipedes to congregate near the surface, large numbers can be destroyed by steam-sterilizing the

soil. Survivors below the zone of sterilization or centipedes coming from out of doors may make another treatment necessary during the cropping season. Apply a lindane spray to the soil between the plants and water it in. The dosage recommended is 5 ounces of a 25-percent wettable powder in 50 gallons of water per 1,000 square feet of bed surface. Equivalent amounts of lindane may be applied in less water as sprays or in dusts, but they should be washed into the soil by watering. For newly set plants use 1 ounce to 10 gallons and pour 1 pint of the suspension around the base of each plant. Do not use lindane for this purpose except in the greenhouse.

Corn Earworm

Corn earworm moths often enter the greenhouses in the fall. The pale-green or brown-striped larvae feed on the tomato fruits, entering through holes either near the stem or on the side. Decay and shriveling of the fruit often follow the insect damage.

Hand picking of infested fruits is usually sufficient to check a light infestation. When an infestation is severe, dust the plants lightly with 3-percent DDT to destroy the larvae while on the foliage.

Mealybugs

Localized infestations of citrus or grape mealybugs frequently become serious on tomato. They can usually be traced to infested ornamental plants brought into the greenhouse for the winter. They are recognized by the cottony masses on the stems and leaves and by the black sooty mold with which they are associated.

When the infestation is confined to a few plants, remove and destroy the plants, rather than resort to control measures. TEPP, sulfotepp, parathion, or malathion in aerosols applied 2 or 3 times at 10-day intervals will usually destroy a larger infestation.

Tomato Pinworm

The tomato pinworm occasionally becomes established in northern greenhouses. The grayish-purple larvae, about one-fourth inch long, bore in the stems, mine the leaves, and tunnel in the fruits, especially near the stems. Pinworms originating from these greenhouse infestations may persist during the summer on potato, eggplant, and horsenettle in the field, and return to the fall crop of tomatoes in the greenhouses. This insect does not survive outdoors in the North.

Omitting the fall crop of tomatoes will control the infestation. Parathion aerosol and 3-percent DDT dust applied at 2-week intervals are effective remedies.

Tomato Russet Mite

The microscopic tomato russet mite, an outdoor pest in the warmer sections of the country, occasionally becomes established on tomatoes in northern greenhouses through purchases of infested plants. The mites feed on both surfaces of the leaves and on stems. As they increase rapidly, the leaves become papery and the plants may die.

The mites may be controlled with sulfur dust or parathion aerosol, applied twice 2 weeks apart.

Armyworms

Armyworm moths enter the greenhouses in the fall, and the brown-striped larvae feed on foliage and chew out large areas in the side of fruits.

Malathion and parathion aerosols and a 3-percent DDT dust are toxic to the larvae and one of these should be applied whenever the larvae are observed.

Cutworms

Dull-black caterpillars hatch from eggs laid by moths migrating from out of doors. They cut off newly set plants at night and hide in the soil by day.

Apply a 10-percent DDT or toxaphene dust over the bed surface at the rate of 20 pounds per acre, or ½ pound per 1,000 square feet. Do not disturb the soil for several days after treatment, to allow time for cutworms to contact the insecticide. Parathion aerosols destroy cutworm larvae much as they do armyworm larvae.

Cabbage Loopers

Cabbage looper moths enter the greenhouses late in the fall, and the pale-green larvae hatching from their eggs feed voraciously on the foliage.

Prompt control measures are essential. Parathion aerosol and DDT dust and aerosol are toxic to cabbage loopers.

Greenhouse Leaf Tier

Slender green larvae occasionally attack tomatoes by tying the leaves together and feeding on the underside. They are the young of the triangular brown moths of the greenhouse leaf tier. Infestations of leaf tiers in tomato houses are usually traced to other crops, such as chrysanthemums or snapdragons, that accompany or precede the tomato crop.

Two applications 10 days apart of parathion or DDT aerosol or 3-percent DDT dust destroy these pests.

Control Measures for Small Greenhouses

In greenhouses too small for proper application of aerosols the following treatments are recommended:

A spray containing 2 teaspoonfuls of 40-percent nicotine sulfate and ¼ teaspoonful of a household detergent per gallon will control aphids and mealybugs. A spray containing rotenone is effective against whiteflies and thrips, and fairly effective against spider mites.

A 3-percent DDT dust or a spray containing 2 level tablespoonfuls of 50-percent wettable DDT powder per gallon is effective against thrips, greenhouse leaf tiers, armyworms, corn earworms, and tomato pinworms. Light dusting with sulfur will destroy the tomato russet mite.

Combustible powders or smokes containing nicotine for aphids and other suitable toxicants for whiteflies and spider mites may be procured in various-sized units for use in small greenhouses.

Hand picking of larvae of corn earworms, armyworms, cutworms, and leaf tiers is practicable and effective in small greenhouses.

Sanitation

Most of the pests that attack greenhouse tomatoes move into the greenhouse in the fall from favored hosts among nearby field crops, weeds, or ornamental plants. It is therefore important to avoid growing susceptible crops near the greenhouse. Destroy weeds and other plants growing near the greenhouse. In late summer or fall clean out all plant debris and fumigate the house with parathion aerosol or sulfur. If possible, sterilize the soil with steam or methyl bromide. Such practices of sanitation will greatly reduce the need for pesticides on the growing crop.

Precautions

To avoid excessive residues on tomato plants and fruits, use all insecticides at the recommended application rates. To avoid plant injury, stunting, or abnormal

growth, use preparations containing highly refined toxicants. This is especially important in the use of DDT and lindane. Aerosols containing parathion, TEPP, sulfotepp, and malathion are extremely toxic, and should be used only by a trained operator, who will asume full responsibility and enforce the precautions prescribed by the manufacturers. The operator should wear protective clothing, gloves, and a full-face gas mask with an approved canister and should wash with soap and water after working with aerosols.

Do not use malathion on tomatoes within 10 days before harvest or sulfotepp or parathion within 15 days before harvest. Do not apply TEPP aerosol to tomato plants before the first flower clusters form, as younger plants may be injured by this aerosol.

HARVESTING AND MARKETING

When greenhouse tomatoes are grown for local market they are usually harvested as they approach full-ripe color and are still firm. The major part of the greenhouse crop is marketed locally and in nearby cities and towns. In those cases where tomatoes must be shipped to more distant markets, it sometimes may be necessary to pick the fruits at the "breaker" stage of maturity—when the first spot of pink becomes visible. Such fruits will not have quite the same high quality that they would have attained had they been left on the vines until firm ripe.

Growers should carefully adjust time of harvesting tomatoes according to the length of time it will take to place the fruit on the market after it is picked. The nearer tomatoes approach full ripeness on the vines the heavier and more flavorful they will become. Therefore they should always be picked as close to firm ripeness as marketing circumstances will permit.

Usually fruits are harvested 2 to 3 times a week. During warm weather the best time of the day to harvest is during the early morning so the fruit will be cool when it reaches the packing room.

Practically all greenhouse-grown tomatoes are clipped or broken from the vines with green sepals attached, and this distinguishes them from field-grown tomatoes. Very few greenhouse tomatoes are marketed with the stems removed as is the common practice when harvesting field-grown tomatoes. Most of the stems are clipped close to the green sepals with small shears or fruit clippers such as are used in harvesting citrus fruits. The clipper blades should be short and rounded at the tips so the tomatoes will not be punctured. Each fruit is held with one hand while its stem is being clipped off close to the calyx. It is desirable to leave no protruding stems to puncture adjacent tomatoes, especially when harvesting and packing the larger fruited varieties such as are grown in Ohio. In regions where the small forcing varieties are grown it is the common practice to harvest greenhouse tomatoes by breaking the fruit stem at the joint beyond the green sepals. Although this method leaves a short stem on each fruit protruding from the calyx, the growers experience little or no damage to these firm lighter weight tomatoes due to stem punctures.

In large establishments hand trucks are used to transport the baskets of picked fruit to the packing room. The tomatoes are sorted, graded, and packed according to size, quality, and market demand. On the market the well-colored fruits with stems and green sepals attached distinguish greenhouse-

grown tomatoes from those that are field grown. The "green-wrap" tomatoes shipped from southern fields have all stems removed before they are packed for shipment.

On the markets greenhouse tomatoes are judged somewhat by the freshness and greenness of their sepals, as this is an index to the length of time the fruits have been removed from the vines. Fresh sepals on full-ripe fruits indicate that they were recently harvested when practically ripe. Tomatoes with stems attached lose moisture more slowly and will keep fresh for a longer time than those with stems removed.

Various types of packages are used for marketing hothouse tomatoes. A commonly used package is a veneer basket holding 10 pounds of fruit. Some growers market their tomatoes in square splint baskets holding 16 pounds. This is a convenient size for handling but is not so large that the tomatoes are likely to become bruised in the bottom of the basket when marketed locally. Fiberboard boxes are replacing wooden containers in many places. Hothouse tomatoes produced in the North Central States are now commonly packed in 8-quart fiberboard baskets with over handles similar to the basket of that size illustrated in figure 9. Some markets, such as Indianapolis, now pack 8 pounds of greenhouse tomatoes per basket; other markets use 10-pound baskets.

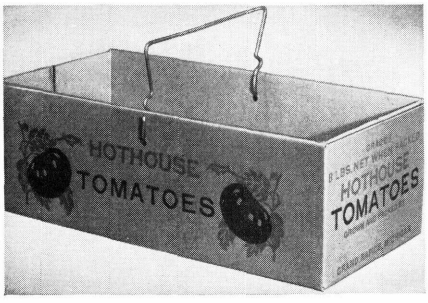

FIGURE 9.—*A fiberboard basket now popular for marketing greenhouse tomatoes.*

In the Northeast most of the greenhouse tomatoes going to Boston are packed in a 15-pound fiberboard carton that is gradually eliminating the bushel box. It is 12 inches wide, 16¼ inches long, and 4½ inches deep.

For distant shipments regardless of the type of package used, each tomato should be wrapped separately before packing in shipping container and padded liners shou' be provided on the bottom and c. the top of the shipping box to af ford protection against bruising in transit.

Some types of containers such as splint baskets that are used in marketing hothouse tomatoes are regulated as to size and shape by the Standard Containers Act and must conform to its specifications. The grower should be sure that the containers he is using conform to the law and that they are properly stamped.

UNITED STATES STANDARDS FOR GREENHOUSE TOMATOES

When tomatoes are sold by grade the grower who has produced a fancy pack is justly rewarded for his extra effort and expense in growing and marketing a high quality product. The Federal grades for greenhouse tomatoes established by the United States Department of Agriculture serve as a basis for their sale and purchase. More complete information on tomato grade and standard container specifications may be obtained from the Agricultural Marketing Service, U. S. Department of Agriculture, Washington 25, D. C. Careful harvesting at the right stage of maturity, avoiding bruising or breaking by rough handling, and proper grading will help insure better prices for the crop.

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